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Revision of the sound insulation requirements in broadcasting studio centres

R. Walker, B.Sc.(Eng.)

Research Department, Engineering Division
THE BRITISH BROADCASTING CORPORATION

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REVISION OF THE SOUND INSULATION REQUIREMENTS IN BROADCASTING STUDIO CENTRES

R. Walker, B.Sc.(Eng.)

Summary

The BBC sound insulation requirements within studio centres have been based on a report published in 1968. Since that time, there have been new measurements of sound pressure levels in studios, control rooms and other areas, and new background noise level criteria have been proposed for programme areas. Both of these factors affect the amount of sound insulation which is necessary to avoid interference between areas, and this report is based on the earlier work. The method by which any sound insulation criterion can be derived is included. It also gives, in the form of a chart, the sound insulation criteria for a range of areas sufficient to cover most requirements in a studio centre, based where appropriate on the new sound pressure level data and the new background noise level criteria.

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REVISION OF THE SOUND INSULATION REQUIREMENTS IN BROADCASTING STUDIO CENTRES

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REVISION OF THE SOUND INSULATION REQUIREMENTS IN BROADCASTING STUDIO CENTRES

R. Walker, B.Sc.(Eng.)

1. Introduction

In any broadcasting centre, sound insulation must be provided between areas, both to prevent unwanted sounds from being audible on the programme output and, in control areas, to avoid distraction of the operators who are trying to assess and control the programme quality. It is also desirable to control the ingress of external sounds, such as traffic on nearby roads and overflying aircraft. In residential areas especially, it is sometimes desirable to limit the sound emission from inside the centre, although this generally follows as a consequence of the insulation provided to protect the programme area from external sounds. In addition to these more obvious cases, there is a requirement to acoustically isolate the control area (cubicle) from the studio to which it is attached. This is to enable the operator properly to assess the sound quality of the programme as picked up by the microphone; it is especially necessary in those areas where the monitored sound is delayed by many milliseconds in coming from the replay head of a tape machine being used to record the programme.[1] Such isolation is also necessary to avoid the modification of the acoustic characteristics of the studio by feedback from the monitoring loudspeaker.

Some programme sources are capable of producing very high sound pressure levels in the area in which the programme is being made (source area) and it is self-evident that high degrees of sound insulation will be required to reduce the interference to an acceptable level in an adjacent area. The level to which the interference must be reduced depends on the existing background noise level in the area which is potentially susceptible to the interference (receiving area). It is an established psycho-acoustic fact that the interference will be inaudible if the sound pressure level of the interference in any critical band* of frequencies never exceeds the sound pressure level of the existing background noise in the same frequency band.[5] Ideally, background noise levels in programme areas should be equal to or lower than the threshold of hearing, and the insulation enclosing the area should be sufficient to reduce the interference from any adjacent area to the same threshold level. However, such ideal conditions would be extremely difficult and expensive to achieve. Compromises have to be made between the permissible levels of background noise and interference and the cost of providing better conditions.

The permissible background noise levels were previously established in 1967.[6] The consequent insulation requirements were calculated based on existing source-area sound-pressure levels and these background noise criteria and issued as a set of sound insulation criteria.[7] Since then a thorough study has been made of the sound pressure levels in a wide range of programme areas,[8] and a set of revised background noise level criteria have been proposed.[9] Both of these factors affect the sound insulation requirements so it has been necessary to revise the insulation criteria. The opportunity has also been taken to modify the scope of the original report,[7] which specified the insulation criteria in accordance with the typical types of construction then in use, and to improve the presentation of the criteria so that more of the original information about the insulation requirements is available to the architect. It is the architect who has ultimately to chose the type of sound-insulating partition to be used in any particular circumstance.

2. Basis of the calculation of sound insulation requirements

The sound insulation performance required at one frequency of any partition separating two areas is a function of three variables. These are the sound pressure level of the potentially interfering sound in the source area, the background noise level in the receiving area from noise sources other than the potential interference, and the 'masking effect'.

References 2 to 5 show that, as a result of masking, an interfering sound will be inaudible if the sound pressure level of the interference is always less than the existing background noise sound pressure level in every critical band. If both of the sounds have spectral distributions

* Critical band is a measurement used in psycho-acoustics to denote that band of frequencies within which masking of an interfering tone will occur.[2,3,4] It is a complex function of frequency and has been established by experiment. It is approximately 1/3-octave wide at 150-200 Hz and much less ($\simeq$ 1/20-octave wide) above 1.2 kHz.

which do not change rapidly as functions of frequency (i.e. are locally uniform), then this inconvenient basis of critical bandwidth can be replaced by the much more convenient octave or 1/3-octave basis. Fortunately, in most cases the peak sound pressure level of the interfering sound and the background noise level are locally uniform and can be so simplified. Special cases, such as interference from mechanical sources which may have very irregular spectral distributions and which may in extreme cases only radiate noise at isolated frequencies fall outside the scope of this report and should be given special consideration. For the remaining cases which constitute the majority of interference problems it is simply necessary to install sufficient sound insulation to ensure that the peak sound pressure level of the interference in the source area is reduced by the insulation to be equal to the background noise level in the receiving area in each frequency band. For the purpose of this work it has been judged to be sufficient to specify the frequency bands as being one octave wide, although measurements of the final result are normally made in 1/3-octave bands in order to show any deficiencies in more detail. No allowance has been made in this work for multiple interfering sources. It is thought that the probability of two potential sources of interference simultaneously reaching their permitted peak sound pressure levels in the same frequency band is sufficiently low to be neglected.

In laboratory work, sound insulation is specified by a Sound Reduction Index (SRI), and performance is measured using a standard size of insulating panel. This method takes into account the effect of the reverberation time of the receiving area; it gives a measurement which can be related to the theory of sound transmission. In the field however this measurement is not directly applicable.

The purpose of a partition is to reduce the sound pressure level in a particular source area by a given amount in a particular receiving area. This reduction in sound pressure level can be measured directly by generating a known level in the source area and measuring the resulting level in the receiving area. The sound pressure level difference is specific to that particular combination of areas and partition. The same construction of the partition could give different results in other situations. The relationship between the sound reduction index and the sound pressure level difference, D, is given by

$$\mathrm{SRI} = \mathrm{D} + 10 \log_{10} (A(1-\bar{\alpha})/(S\bar{\alpha}))\ \mathrm{dB} \qquad (1)$$

where A is the area of the partition, S is the surface area of the receiving room and $\bar{\alpha}$ is the mean sound-absorption coefficient of the receiving room. The remainder of this report is only concerned with the difference, D. The appropriate correction factor, usually in the range +6 dB to −6 dB, derived from Equation (1), must be calculated and applied during the detail design of a particular partition.

All of the results and criteria presented in this report are based on the differences between the peak sound pressure levels in the source areas and the background noise criteria for the receiving areas, taken in octave-band intervals.

3. Present criteria and reasons for revision

The sound insulation criteria used up to now were first specified in 1968[7] and, in areas which meet both the background noise criteria and the sound insulation criteria, they have proved to be reasonably satisfactory for most of the time. However, some areas recently completed have had background noise levels much lower than the relevant criterion and complaints about inadequate insulation have been made by the operating personnel. One such case was the sound insulation between Studio 4 and control Cubicle 3 in the new Manchester Studio Centre. The original insulation exceeded its' criterion at all frequencies except 50 Hz and 63 Hz. Nevertheless, complaints were received and the insulation was subsequently improved, fortunately by a simple structural change, by an average of 23 dB in order to suppress this interference. This case illustrates clearly the effect of the receiving area background noise level on insulation requirements.

The effect can be illustrated graphically by adding the measured background noise level in the receiving area, Fig. 1, to the measured insulation between the areas, Fig. 2, for each frequency band. The result is a characteristic which is the maximum sound pressure level in the source area which will be just not audible in the receiving area, and can be plotted on the sound pressure level probability curves from Ref. 8 for the appropriate type of source area. Fig. 3(*a*) shows the results for the case of interference from Manchester Cubicle 3 (a small drama cubicle) to Studio 4, as originally constructed.

The probability of audible interference can be seen to be greatest at a frequency of 200 Hz (as a result of a weakness in the insulation at this frequency) and reaches a maximum value of more

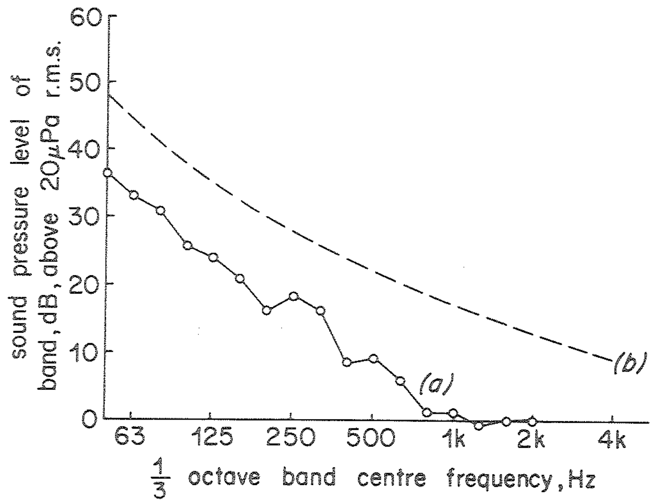

Fig. 1 - Background noise level, Manchester Studio 4

(a) measured background noise level

(b) background noise level criterion

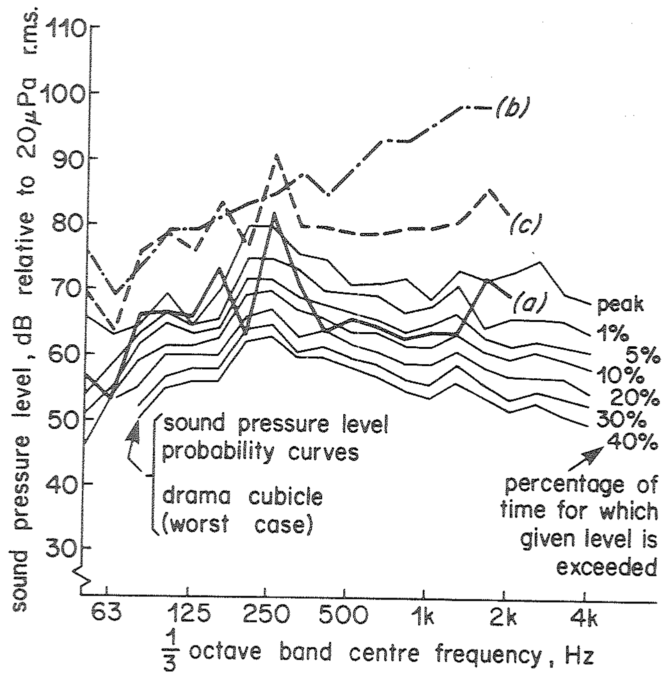

Fig. 3 - Interference probability levels, Manchester Cubicle 3 and Studio 4

(a) as constructed (b) after improvement in sound insulation

(c) as constructed, if the studio background noise level had been equal to the criterion

than 30%. This characteristic is for a sound insulation which satisfied the insulation criterion for that situation (except at 50 and 63 Hz) and which prevailed at the time at which complaints were received about inadequate insulation. Fig. 3(*b*) shows the result of the same calculation for the improved sound insulation and shows that the probability of audible interference was reduced to zero at all frequencies. No complaints about inadequate insulation have been received since this modification. However, the third characteristic, Fig. 3(*c*), shows the result which would have been obtained had the background noise level in the receiving area been equal to the appropriate criterion, rather than 10 dB to 15 dB lower. The probability of audible interference is nowhere greater than 1% (at 200 Hz) and zero at all other frequencies. It is probable that this characteristic

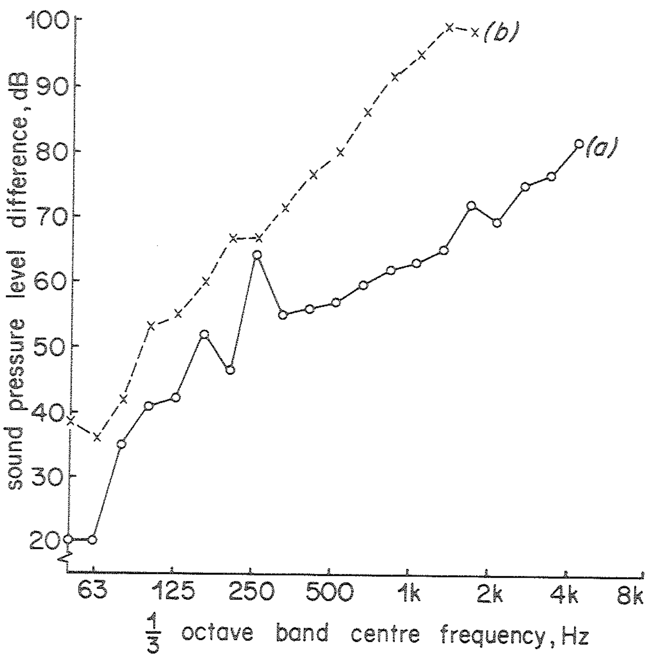

Fig. 2 - Sound insulation, Manchester Studio 4 to Cubicle 3

(a) original construction

(b) after installation of additional insulation

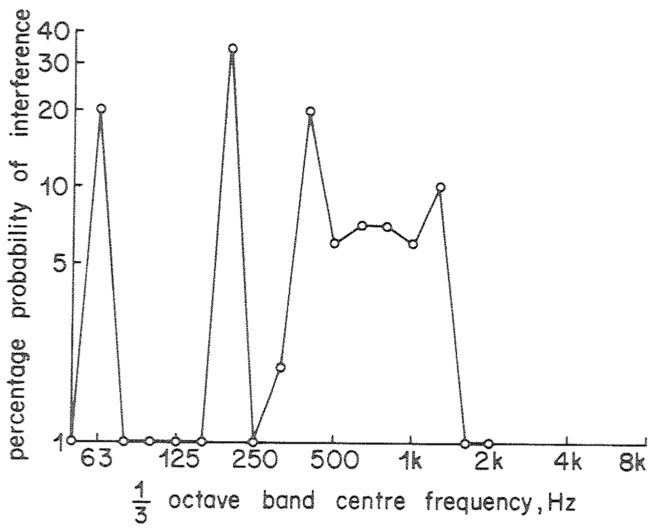

Fig. 4 - Probability of audible interference, Manchester Studio 4 from Cubicle 3 (as originally constructed)

would have been satisfactory as it is somewhat better than a large number of programme areas from which no specific complaints about inadequate insulation have been received. Using graphs of the type shown in Fig. 3, an alternative presentation of the same results can be obtained by plotting the probability of audible interference as a function of frequency. Fig. 4 shows such a plot of the original result from Fig. 3(*a*). The results for the other two conditions, Fig. 3(*b*) and Fig. 3(*c*), do not exceed 1% and are therefore not within the range covered by Fig. 4.

4. Revision of the insulation criteria

4.1. Revision of the background noise criteria

4.1.1. Programme areas

With progressive improvements that have been made in the programme-signal chain, the contribution of the acoustic noise in the studio to the final background noise level of the programme-signal as received in the listener's home has become significant for some types of programme. In some cases, for example a talks studio with a quieter than average speaker, this acoustic noise contribution can be dominant. A study of the noise contributions was carried out which concluded that the permissible *total* background noise should be reduced by 5 dB relative to the 1967 criteria for most studio areas.[9] This study also revealed that a misinterpretation of the 1967 criteria has been resulting in background noise levels about 3 dB higher than was intended by those criteria. This arose because the criteria were intended to be total background noise level from all sources, whereas in practice these levels had been applied to the ventilation noise alone. The background noise levels due to ventilation, on which the new insulation criteria are based, are therefore apparently 8 dB lower than the 1967 criteria in most cases. Fig. 5 shows the new criteria, in 1/3-octave bands, which are to be applied to ventilation noise. These new background noise criteria, converted to octave bands are the levels on which the insulation requirements calculated in this report are based. Ventilation rather than total noise levels are used as the basis because of the potentially great day to day variation of noise levels due to other sources.

4.1.2. Echo room

To be useful as general purpose facilities, the background noise level in echo rooms should be sufficiently low not to significantly worsen the signal to noise ratio for the most critical type of programme, namely drama. Echo rooms are usually operated at high sound levels in order to maximise the output signal to noise ratio. As in Reference 7, it has been assumed that the peak sound pressure level in an echo room which is being used for drama will be 10 dB higher than in the associated studio. Therefore the background noise level need be no lower than +10 dB relative to the most stringent criterion, given in Fig. 5(iii). Because of the 5 dB spacings between the criteria for programme areas, this is the same as the least stringent criterion, Fig. 5(i).

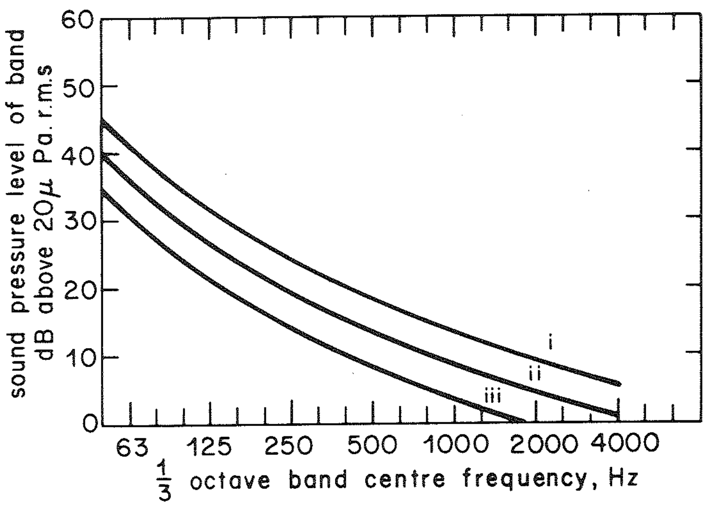

Fig. 5 - Recommended new criteria for maximum tolerable background noise in studios from ventilation

(i) Radio – other than classes (ii) and (iii)

(ii) Radio – talks, continuity, recital. Television all categories

(iii) Radio – drama

4.1.3. Reverberation plate room

Reference 7 states that a reverberation plate 'may be kept in any quiet room provided that precautions are taken against contact with the casing', the implication being that the room could also be used for other purposes. However, comments from users of plates located in such areas gave reason to doubt this. A series of measurements carried out on a reverberation plate (results in Appendix 2) showed that the acoustic breakthrough from the room to the plate output became equal at certain frequencies to the electrical background noise level of the plate if the level of the external acoustic noise exceeded the background noise criterion for a private office as given in Reference 7. Typical noise levels in a quiet, occupied office would result in measurable interference at all frequencies below about 400 Hz. The 50 to 55 phon level, stated by Kuhl[14] to be adequate, is also shown to be too high at all

frequencies below 315 Hz. The measured insulation characteristic also shows the weakness between 125 Hz and 250 Hz which could result in 'howlround'* if the plate were to be installed in the control cubicle. This confirms the requirement that reverberation plates should be installed in areas where the total ambient noise level does not exceed the criterion for a private office as given in Reference 7, and included here in Appendix 1.

4.1.4. Offices

As in Reference 6, the background noise level criteria for general offices and canteens/kitchens have been chosen to conform with characteristic NR55[15] and with the current ISO recommendation for such areas.[16]

The criterion for a private office, given in Reference 6 as a curve near to NR40,[15] has been slightly altered to conform exactly with NR40, within the range specified in the current ISO recommendation for private offices.[16] This is 2-3 dB higher than the level proposed in Reference 6 and which was used to calculate the earlier insulation criteria (Reference 7).

4.2. Study of source peak sound pressure levels

4.2.1. Radio studios and cubicles

Reference 8 describes a study, carried out in 1971-72, of the sound pressure levels encountered in a wide range of radio studios and cubicles. In addition to measuring the peak sound pressure level as a function of frequency in each area, the probability distributions of the sound pressure levels were also measured.

To obtain a reasonably error free assessment of the peak sound pressure level as a function of frequency, the relative spectral distributions of the peak level and the levels which were exceeded for 1% and 5% of the time were averaged. This gave a typical spectral distribution of the loudest parts for each programme type. The level of this average spectrum was then adjusted until the 'A-weighted' (IEC) sound pressure level of the average spectrum was equal to the 'A-weighted' sound pressure level of the loudest observed sample for each programme type. This procedure resulted in a peak sound pressure level as a function of frequency which was very nearly the same as the observed peak sound pressure level but with the significance of the random errors introduced by the statistical nature of the measurement procedure reduced.

4.2.2. Television studios

Television studios differ from radio studios in two major aspects which are relevant to the sound insulation requirements. The more important of these is that, excepting small 'insert' and 'news' studios, the useage of a television studio cannot be specified in the same way. Sufficient sound insulation must be provided to prevent the noisiest types of production from interfering with nearby areas. However, because the studios are very much larger than most radio studios, the cost of providing such insulation is high (although this factor is partially offset because of the associated apparatus rooms which limit the proximity of studios). The second difference is that television studios cannot be run to such a full schedule because of the time which must be allowed for scenery shifting and other non-sensitive operations. This allows a small degree of flexibility in the studio scheduling which could be used to ensure that nearby areas are not sensitive to interference during the making of a particulaly noisy programme.

Thus, the insulation criterion for a television studio cannot be specified as accurately as it can be for a radio studio. For the purpose of this report it was decided that it would be unrealistic and uneconomic to specify an insulation criterion for every television studio on the basis that it would contain a 'pop-group'.* Therefore the basis used to calculate the sound insulation was chosen to be the peak sound pressure level generated by the next loudest category of source type — a symphony orchestra.

Small, single purpose television studios used mainly for speech, such as news, interview or presentation studios have been assumed to have the same peak sound pressure level as a radio talks studio as a source of interference.

4.2.3. Listening rooms, dubbing theatres and all television control rooms

The arguments used above in Section 4.2.2

* Howlround is acoustic/electrical feedback round a closed loop which has a net power gain greater than unity.

* The term 'pop-group' is commonly used to describe a group of musicians using electronically amplified instruments to play popular music. Up to the time of writing, it has been the practice amongst such musicians to reproduce the sound at a very high level (levels 10-15 dB higher than the peak sound pressure level generated by a symphony orchestra have been measured).

in relation to television studios apply in a similar way to television control rooms. The peak sound pressure level in television control rooms has been assumed to be the same as in the cubicle of a radio orchestral music studio. Listening rooms and dubbing theatres have also been assumed to be the same.

4.2.4. Echo rooms, scenery dock and construction areas, canteens and kitchens, garages

The data on peak sound pressure levels for these areas were taken from Reference 7, there being no reason to suppose that they are no longer valid. In the case of garages, the difference between peak uncontrolled level and the lower 90% level is so large that some control over the movement of the noisiest 10% of vehicles is worthwhile. Thus garages have been considered in two separate categories depending on whether control is exercised or not.

4.2.5. Apparatus rooms

No direct figures were available for the peak sound pressure levels in an apparatus room but an analysis of the figures given for sound reduction requirements in Reference 7 shows that an apparatus room can be 2 dB worse as a source of acoustic interference than a private office. This value has been used in the preparation of these new sound insulation criteria.

4.2.6. Offices

The data on peak sound pressure levels in both general and private offices were taken from Reference 7. However some private offices in the BBC are equipped with facilities for listening to disc or tape recordings. The peak sound pressure level in these areas can be much greater than in offices not so equipped, and a separate area category has been introduced to accommodate this use. A survey of such offices was carried out in order to establish the peak sound pressure levels. The results of this survey are included in Appendix 1.

4.2.7. Plant rooms

The data for peak sound pressure levels in plant rooms used to calculate the interference criteria of Reference 7 were based on the reciprocating type of refrigerant compressors then in use. Since that time, centrifugal compressors have been used in large installations. Whereas reciprocating compressors produce a sound pressure level distribution which is highest at low frequencies, the centrifugal type emit less low frequency noise but very high levels of high frequency noise. As it is so much cheaper to provide high frequency sound insulation (see Section 5) than it is to provide low frequency insulation the centrifugal type is to be preferred, despite its apparently very high level of noise emission.

Measurements have been made (August 1979) on a centrifugal compressor recently installed at Television Centre. The data given in Appendix 1 for the peak sound pressure levels is the higher of the two levels, one for reciprocating and one for centrifugal compressors, at each frequency. The proposed insulation criteria were based on this combined spectrum.

These criteria are valid for the largest type of plant room with either type of compressor. However, the size and contents of a plant room depend on the size and requirements of the building which they serve. The range can be from a small room, containing only air-handling equipment (which has a very low level of noise output) to the very large installations used as the basis for the criteria laid down in the present work. It is uneconomic to install the sound insulation required by a large, noisy plant in cases where it is not required. Therefore, all plant rooms should be considered individually and the required insulation calculated, using the method described in Section 5, together with either the manufacturer's figures for noise output or measurements made on identical plant which is already installed elsewhere.

4.2.8. Aircraft noise

The data for the sound pressure levels produced at ground level by overflying aircraft were those used in Reference 7 to calculate the required roof insulation and were taken from References 6 and 11. This opportunity was taken to check the current validity of these figures by searching published work on aircraft noise. It was found that very little information in the form of octave band analysis has been published, the majority of the results being in the form of single figures either 'A-weighted' or 'perceived noise level, P_N'. These types of results are of little value for the purpose of designing partitions to meet specific background noise level criteria.

However, one detailed set of results (Reference 12) relating to the insulation of a single house against aircraft noise is relevant. This showed that the worst case sound pressure levels were approximately 6 dB higher than the figures given in Reference 11 for frequencies up to 1 kHz

and somewhat less (−10 dB at 4 kHz) at higher frequencies. This house was located only 800 metres from the end of the runway and 400 metres off the centre line of the runway. It was in an area of open countryside where the noise abatement procedures might not be so strictly adhered to as over densely populated areas. Studios are not normally located so near to an airport. If the same peak sound pressure level figures as were used for Reference 7 are used to calculate the new insulation criteria, then the results from Reference 12 imply that the insulation will be sufficient at all frequencies assuming that the studio is more than about 3–5 km from the end of the runway and that the aircraft maintains the initial rate of climb. If the rate of climb reduces to one half of the initial rate, the safe distance will be 5½ to 8 km from the end of the runway. The results published originally in Reference 7 are thus judged to be still valid for typical studio locations.

4.2.9. Traffic noise

The figures used to calculate the insulation criteria in Reference 7 for the peak sound pressure levels produced in the vicinity of external studio walls by heavy urban traffic were taken from Reference 6. This opportunity was also taken to check these figures in the same way as for aircraft noise (Section 4.2.8). One set of detailed results[13], slightly more recent than the work recorded in Reference 6, and a new measurement on the façade of Broadcasting House, London (June 1979) confirmed that these figures are still valid.

5. Calculation of the new sound insulation requirements

As outlined in Section 2, the sound insulation required at any frequency to isolate any area from any other area must be greater than the difference between the peak sound pressure level in the source area and the background noise level in the receiving area. For any pair of areas, two such insulation requirements can be derived, depending on which of the two areas is considered to be the source. In establishing insulation criteria, the higher of these two characteristics must be chosen. In most cases, the insulation requirement in one direction is much greater at all frequencies than in the other direction and the choice is obvious. However in some cases the insulation requirement characteristics cross over and, in these cases, the higher value must be taken at each frequency to derive a composite characteristic.

To cover all possible combinations of areas, the 30 area categories were taken in pairs and the required insulation characteristic derived in octave frequency bands for each pair for the range of octave band centre frequencies from 63 Hz to 8 kHz. A typical example, for the case of a partition between an orchestral music studio and a drama studio is shown in Fig. 6. Approximately 360 such characteristics are required to cover all possible combinations of areas.

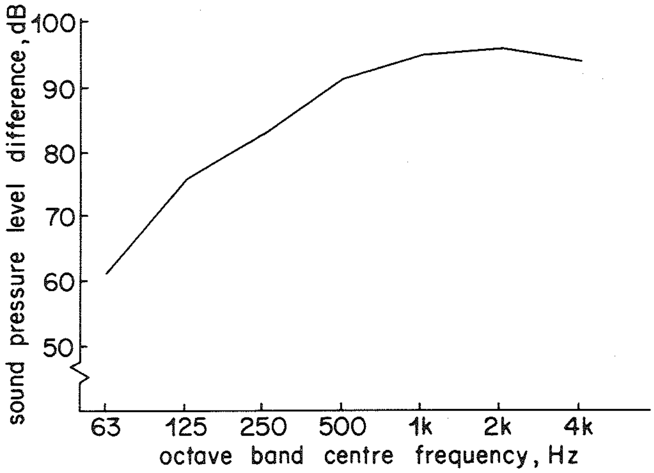

Fig. 6 - Sound insulation requirement between orchestral music studio and drama studio

6. Presentation of the criteria

6.1. General

It is obviously impractical to produce a comprehensive set of insulation requirements which require the preparation and distribution of about 360 separate drawings. A method had to be found to reduce the amount of information presented whilst retaining the major features of the characteristics. The method used in Reference 7 was to present the criteria as a chart. The insulation criterion between any two areas was presented as a series of numbers at the intersection of a row and a column representing the two areas. In this way, provided that each insulation requirement *can* be reduced to a simple series of numbers, a single chart can give the criteria for any possible combination of areas. This method has proved to be satisfactory and was used again in this revision of the insulation criteria. The area categories of the original chart have been slightly altered and some additional categories introduced. This was done to make the chart more representative of current practice and to expand the scope. The main changes are the splitting of control cubicles in radio into separate entries, and the inclusion of 'pop' studios and cubicles and private offices with monitoring facilities. The 'same programme'

category for cubicles and control rooms has been omitted, because of current practices such as monitoring off tape.

6.2. Reduction of the insulation requirement characteristic to simplified form

Fig. 6 shows that, even when specified at octave frequency intervals, the required insulation characteristic is not a simple function. It would be very difficult to design a partition to meet such a requirement exactly. It would indeed be pointless to do so because any partition capable of achieving the higher levels of insulation would have to be degraded by some means at frequencies where the requirement was not so great.

The general shape of the characteristic of Fig. 6, that is low values of sound insulation at low frequencies rising to a maximum level at an intermediate frequency (around 500 Hz – 1 kHz) and remaining at this level or falling slightly at frequencies above 1 kHz – 2 kHz, is typical of all of the requirements and derives mainly from the shape of the background noise level criteria. The small deviations from this regular shape are due to the deviations from a uniform sound pressure level in the source area.

Fortunately, there is a feature of all partitions which, at least in theory, can be used to reduce each sound insulation requirement to a series of consecutive straight lines.

Theoretically, an infinite, limp partition has a sound reduction index which increases by 6 dB for every doubling of the measurement frequency and by 6 dB for every doubling of its superficial mass. Two such partitions, sufficiently far apart to be independent of each other, have a characteristic slope of 12 dB/octave. In practice, as a result of the partition being finite and stiff, the average slope of a single partition is approximately 5 dB/octave. A double partition with a small spacing between the leaves, such as a conventional cavity wall, has leaves which are not far enough apart to be independent and has an average characteristic slope of about 8 dB/octave. These figures actually only apply above the frequency at which the wall mass resonates with the stiffness, i.e. where the characteristic is mass-controlled. For walls of normal construction as used for sound insulation purposes, this resonant frequency is quite low.

For the purposes of sound insulation, the partitions can be divided into four categories:

(1) Single leaf walls: 5 dB/octave

(2) Double leaf construction with a small cavity 50 – 300 mm: 8 dB/octave

(3) Double leaf construction with a large cavity 300 mm upwards: 10 dB/octave:

(4) Triple leaf construction: 15 dB/octave

It must be remembered that these are only approximations and individual partitions may deviate from them, especially at low frequencies. Nevertheless, these categories provide a means by which any required sound insulation characteristic can be reduced to a simple series of numbers.

Given a required characteristic, for example, that shown in Fig. 6, four different lines can be drawn so as to satisfy the requirement as illustrated in Fig. 7. Each of these lines represents a single leaf, a cavity wall, a double-leaf, or a triple-leaf partitions as defined above, and are drawn at slopes of 5, 8, 10 and 15 dB/octave respectively. Each straight line can be specified by two numbers, for example, the sound pressure level difference at 63 Hz and the slope of the line.

Partitions provide an every-increasing amount of sound insulation with increasing frequency, but flanking paths eventually limit the amount of insulation which can be achieved. It is useful, therefore, to also specify a frequency and a sound pressure level difference above which no further increase is necessary to meet the requirement.

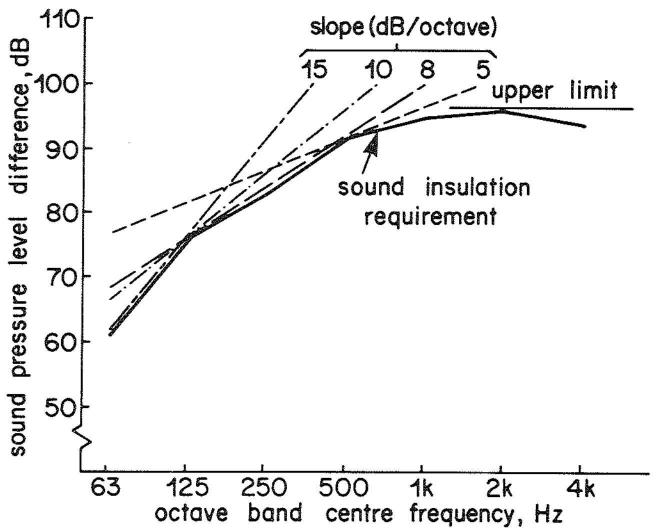

Fig. 7 - Sound insulation requirement between orchestral music studio and drama studio with suitable categorized partition performance

In Reference 7 the required characteristic was specified by four figures. These were a frequency and a sound pressure level difference below which no further reduction in difference was *permitted* and a frequency and sound pressure level difference above which no further increase in difference was *necessary*. In addition, the difference at 500 Hz was given as a single figure guide to the required performance of the partition. There are two shortcomings in this earlier method of presentation. The first is that, despite many references in published work (for example Reference 17), few real partitions of the types normally used to provide sound insulation between areas in a broadcasting studio centre show a 'levelling off' in performance at low frequencies at least within the frequency range considered in this present work. Therefore, the low frequency part of the earlier criterion is unrealistic. Such a requirement can only be met by raising the general level of the insulation curve, so that at no point does it fall below the requirement. This results in a raising of the mid-band insulation figures to values above those which are otherwise necessary. The second shortcoming is that a choice, based hopefully on the normal building practices employed in studio centres, had to be made of one type of partition construction out of the four categories. Having made this choice, a great deal of information about the detail of the requirement was effectively thrown away and was not available to the architect, who was thus no longer free to make a choice of the type of wall construction which best fits in with other requirements. For example, Ref. 7 gives all partitions between an uncontrolled garage and other areas as having a slope of 10 dB/octave, i.e. double leaf. However, if the garage is separated from other areas by main structural walls of single-leaf, but massive construction, these may alone be sufficient to meet the requirements. The architect has no acoustic information available to confirm this. Fig. 8 illustrates this problem, using as an example the requirement between an uncontrolled garage and an area with a background noise equal to 'ii', giving the insulation criterion as obtained from Reference 7 and a single-leaf characteristic which would also be suitable. This problem is also illustrated by the fact that Ref. 7 gives no figures at all for triple leaf partitions, whereas in practice these are not uncommon.

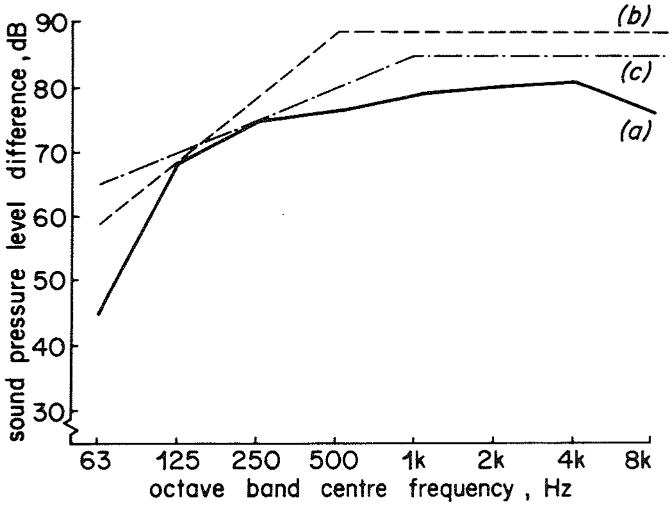

Fig. 8 - Sound insulation requirement between uncontrolled garage and a noise criterion (ii) area showing two possible satisfactory categorized partitions

(a) sound insulation requirement

(b) as Ref. 7; 10 dB/octave, double leaf partition

(c) satisfactory alternative; 5 dB/octave, single leaf partition

A method was sought which could adequately describe the actual requirement at the same time as restricting the amount of information to be presented. If, from Fig. 7 the straight line which is nearest to the actual requirement is chosen at every point, then the result is a piecewise-linear approximation which just exceeds the requirement at every frequency. This is the criterion and can be specified by five numbers, the slopes of the individual portions of the line being fixed at 15, 10, 8, 5 and 0 dB/octave respectively. A sixth number, the frequency at which the criterion becomes 0 dB/octave can also be given as a check that the line has been properly re-constructed.

The final form chosen for the presentation of the criterion was to specify the sound pressure level difference at 63 Hz and at the four intersections of the straight-line portions, together with the frequency above which no further increase

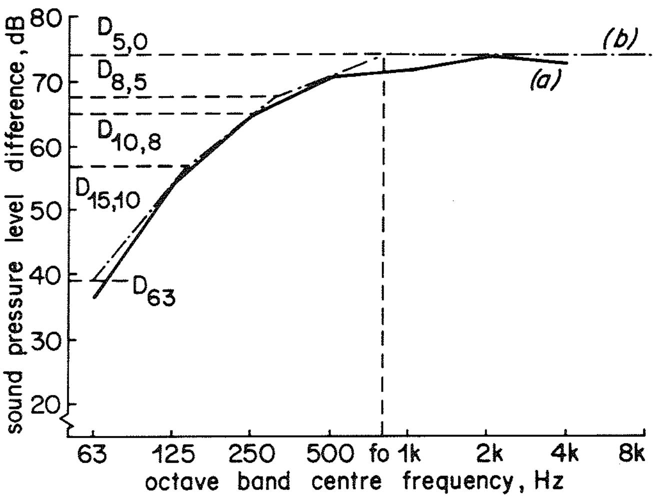

Fig. 9 - Sound insulation requirement and proposed criterion between talks studio and drama studio

(a) requirement (b) proposed criterion

in insulation is required. Fig. 9 shows, as an example chosen at random, the sound pressure level difference requirements between a talks studio and a drama studio. It illustrates that the piecewise linear approximation (criterion) is close to the actual requirement, at least up to the frequency at which the actual requirement begins to fall. It also shows that a good deal of information about the profile is lost if a choice were to be made of the type of construction at the outset, as was done in Reference 7. This method of deriving the criteria results in a similar piecewise approximation to that used in British Standard No. 5821 : 1980, 'Method for rating sound insulation in buildings and of building elements'. Consideration was given to using this British Standard as a basis for specifying the sound insulation criteria between areas in a studio centre. The main reason for not doing so was that, throughout this present work, an attempt has been made to deviate as little as possible from the actual sound insulation requirements in deriving the criteria. In this respect, the BS5821 reference curves are not as good as the method finally used because only three lines are used in the BS piecewise linear approximation; the BS gives a reasonable approach for general building work where triple leaf partitions are rarely encountered. In the more demanding and objective field of broadcasting studio centres a more precise criterion is appropriate.

Unfortunately, there is one drawback to this method. It is difficult to obtain, from the resulting series of numbers, an intuitive idea of the magnitude of the necessary partition construction without actually drawing the graph. However, the main objective of this work was to provide, for the BBC's Acoustics Architect, data on which any partition could be designed. For this purpose, the required sound pressure level difference would normally be plotted for comparison with known wall structures, so the virtual necessity to plot the characteristic is not seen as a serious disadvantage. In addition, a guide to the mass of the partition can be obtained from the figure given for the sound pressure level difference at 63 Hz. At this frequency, the construction of the partition (i.e. single, double or triple) is much less relevant than at higher frequencies.

6.3. The final chart and method of reconstructing a criterion

The sound insulation requirements derived for all of the meaningful combinations of areas as described in Section 5 were converted to sound insulation criteria by the method described in Section 6.2. The resulting sets of numbers were entered into the appropriate spaces in the chart shown in Fig. 10. At each intersection of a row and a column in Fig. 10 the six numbers within the rectangle represent the value of the sound pressure level difference criterion at 63 Hz, and at the four intersections of the lines with slopes of 15, 10, 8, 5 and 0 dB/octave. The numbers are taken from left to right and from top to bottom, beginning with the top left number. The bottom right number is the approximate frequency in hundreds of hertz at which the intersection of the 5 dB/octave and the 0 dB/octave lines occurs. It is included as a check that the criterion has been correctly reconstructed. Appendix 3 gives a description of the method by which the criterion can be reconstructed and discusses the implication of two or more of the given numbers being the same. Some possible entries in Fig. 10 are not valid and are indicated by X. This means that there is no requirement for sound insulation in those cases.

The sound insulation criterion given for partitions between offices or canteens/kitchens and programme areas are for the protection of the programme areas only. In a limited number of cases, this value of insulation would give rise to audible interference in the offices or canteen/kitchen. It is generally uneconomic fully to protect such relatively unimportant areas. However, a subsidiary chart showing the insulation required to protect these areas is given for completeness in Fig. 11.

7. Subdivision of area types

An attempt has been made to categorize all of the possible types of area which might exist within a broadcasting organisation and to minimise the total number of different categories.

Inevitably, some types of area will have been omitted and other may have been assigned to slightly unrealistic categories. In attempting to produce a compact yet comprehensive set of insulation criteria this is unavoidable. For such cases, the method used to derive the given criteria can be applied provided that the peak source sound pressure levels are known or can be calculated.

8. Discussion of results

8.1. Reasons for increases in insulation criteria levels

Comparison of Fig. 10 with the equivalent

NOTES:

1. FIGURES GIVEN ARE TO PROTECT THE INTERNAL AREA FROM EXTERNAL NOISE. SITUATIONS REQUIRING LOW EXTERNAL NOISE MAY REQUIRE ADDITIONAL INSULATION.

2. FIGURES GIVEN ARE TO PROTECT PROGRAMME AREAS ONLY. SUBSIDIARY CHART (FIG. 11) GIVES INSULATION REQUIRED TO PROTECT OTHER AREAS FROM INTERFERENCE FROM PROGRAMME AREAS.

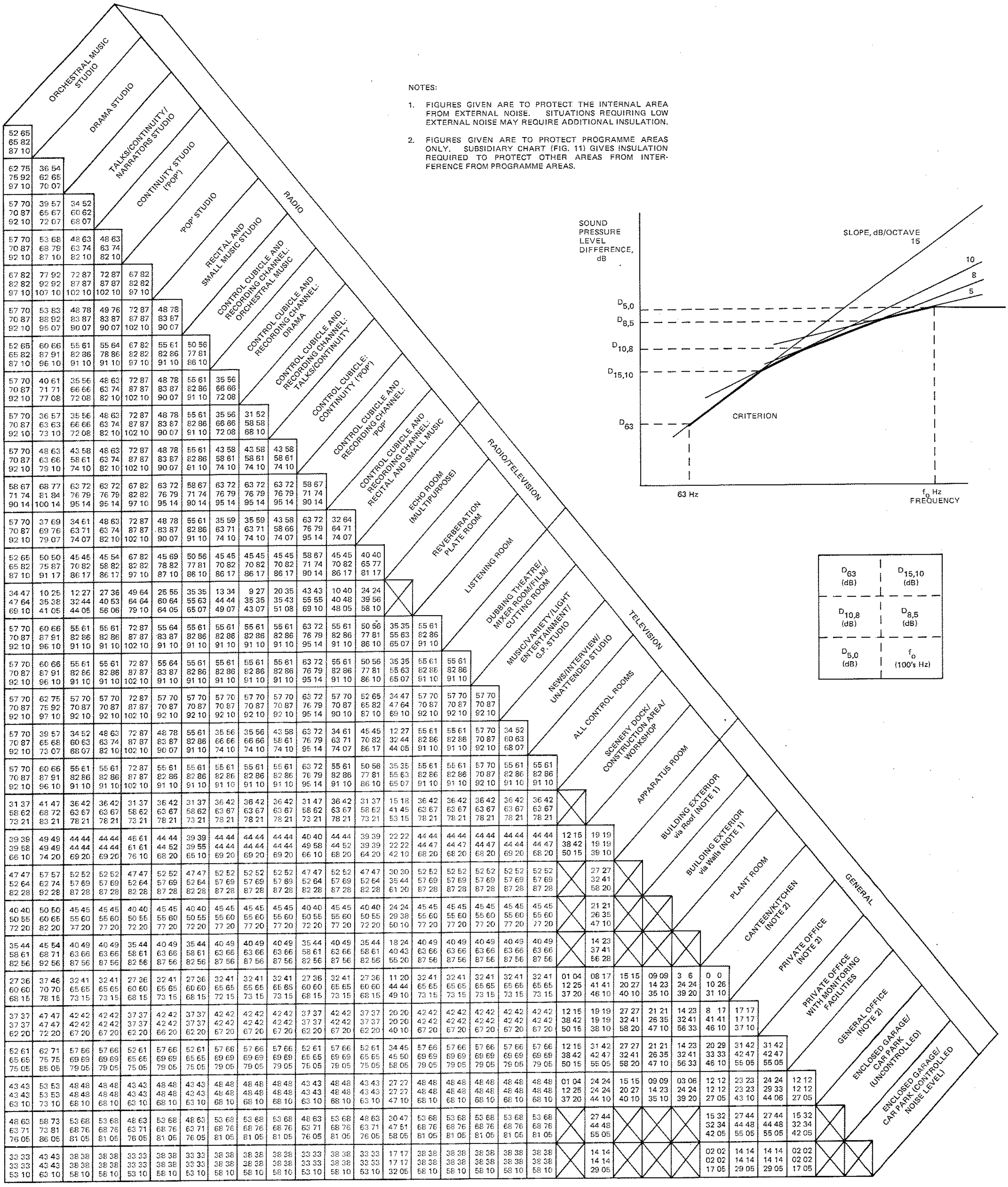

Fig. 10 - Sound insulation criteria

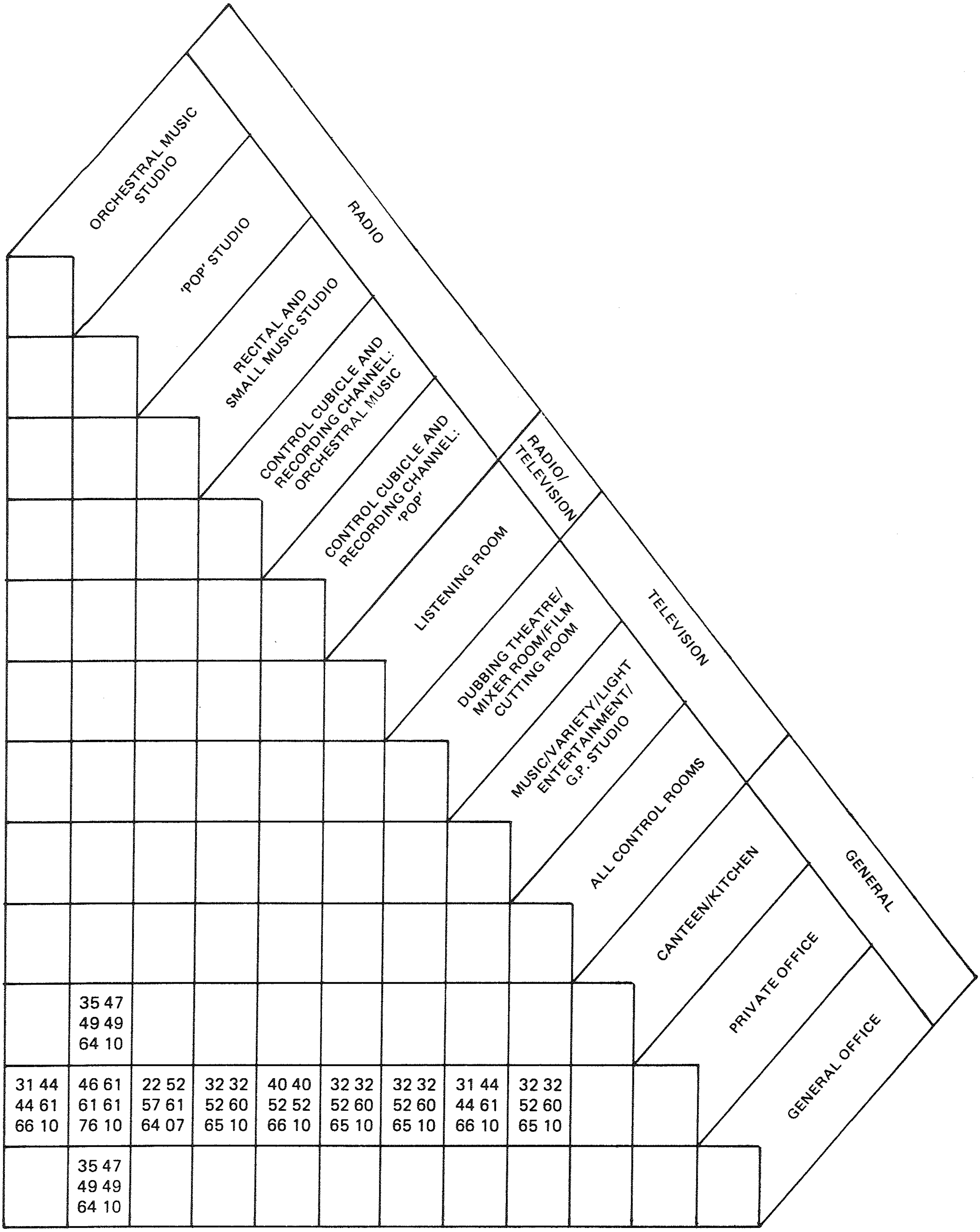

Fig. 11 - Subsidiary sound insulation criteria for the protection of non-programme areas

from Reference 7 shows that most of the insulation criteria are now more stringent than they were in 1968. The main reason for most of these increases is the improvement in the background noise criteria for programme areas. This has resulted directly in an 8 dB increase in insulation requirements in most cases (see Section 4.1.1). However, some of the increases are greater than 8 dB. The more important of two factors responsible for this additional increase is that some of the source peak sound pressure levels actually measured[8] were higher than those used in Reference 7 which were based on less direct methods of assessing the peak sound pressure level. In the case of an orchestral music studio this difference averages about 13 dB. The second factor, which has a less significant effect, is the raising of the general level of the criterion to satisfy the low frequency insulation requirement, as discussed in Section 6.2.

8.2. Effect on building design and costs

The sound insulation requirements derived in this work, given as factors the source sound pressure levels, the receiving area background noise level criteria and that the interference should be audible for less than 1% of the time, are absolute and unavoidable. Apart from those factors, no interpretations or assumptions have been made, at least for those cases where measurements of the source sound pressure levels were available. For the remainder, an assumption has been made about which category each area should be assigned to and this categorization may be questionable in some specific cases.

Some of the sound insulation criteria specified in this work are so demanding that little experience of such structures is available to assist in the design. In most cases, it will be impractical to locate the noisiest types of sources near to any other area. The best partition that has ever been measured between two areas which could be described as adjacent to each other is that between Studio 4 and Studio 5 at the BBC's Maida Vale premises. This partition is a triple leaf construction and consists of two 228 mm (11") leaves and one 456 mm (18") leaf with cavities of 1460 mm and 229 mm (a total thickness of 2.6 m). Both of the studios are resiliently mounted on antivibration pads and the greatest care was taken during their construction. It achieves a sound pressure level difference of 65 dB at 63 Hz, rising to 109 dB at 500 Hz. Nevertheless, it fails to meet the new criterion for insulation between two pop studios by an average of about 5 dB up to a frequency of 250 Hz.

Even the less severe requirements will mean that great care will have to be taken in the specification and construction of partitions if the new criteria are to be met.

8.3. Methods of reducing the insulation requirements

Consideration was given to three methods of reducing the sound insulation requirements. The first was to consider the effect of using a source sound pressure level distribution other than the peak. The levels which were exceeded for 1%, 5% and 10% of the time were considered. Reference 10 indicates that the reduction obtained would be about the same for all types of programme material and would amount to approximately 3.5 dB, 8.5 dB and 11 dB respectively. The peak level is by definition the level which is exceeded for less than 1% of the time, in fact for approximately 0.15% of the time.[10] Although a reduction of 8–11 dB in the insulation requirement would be considerable, it was decided, in consultation with the potential users (via the BBC Acoustics Committee), that a probability of interference of 5–10% would be unacceptably high and result in complaints from the users. Thus the peak source sound pressure level seems to be a reasonable basis from which the insulation requirements can be derived and that a shortfall of about 3.5 dB might be tolerated in some circumstances.

The second method considered was the elimination of the insulation requirement between a studio and its own control cubicle in the studio to control cubicle direction only. This possibility was studied by analysing the insulation requirements for all types of studios. In all but five of the fourteen cases studied, the limiting insulation was that from the cubicle to the studio anyway so that no savings could be made. In the remaining five cases* the allowance that could have been made was about 3–5 dB. It was thought not to be worth complicating the principle of the insulation criteria and of the final chart to include this factor for just five of the approximately 440 chart entries for such a small saving in construction cost.

The third method of reducing the sound insulation requirements and by far the most effective is to limit the peak source sound pressure level. There is some evidence that this method of control is already happening in television control rooms, mainly as a result of the poor sound insulation which was provided in many of the earlier tele-

* These five cases were the typical and worst case results for 'pop' studios/cubicles and recital studios/cubicles and the typical results for orchestral music studios/cubicles.

vision control suites. From the artistic viewpoint this approach is unacceptable but, because the building costs involved in meeting some of the sound insulation criteria specified in this work are very large, it may be uneconomic to do otherwise.

9. Conclusions

A description has been given of the derivation of the sound insulation requirements for studio and other areas and a method has been developed of reducing these to criteria consisting of a relatively simple series of numbers suitable for inclusion in a comprehensive chart.

The results show that, with the very high sound pressure levels commonly experienced in a number of different types of area and with the low background noise level criteria now required, a great deal of sound insulation is required in some cases. This illustrates that such areas should not be close together and that more consideration should be given to this factor in the design of building layouts.

For the remaining less critical areas, the required insulation will only be obtained if care is taken during the design and construction to ensure that no avoidable weaknesses are accidentally built into the structure. Even so, the required insulation will in some cases only be achieved by the use of expensive forms of construction, or again by careful choice of layout in the building design.

However it should be borne in mind that the typical life of a studio is in the region of twenty to forty years and during this period many thousands of programmes will probably be made in it. If proper provision has been made at the outset for meeting insulation and noise criteria then the majority of these programmes will be made without acoustic incidents, like the distruption of the recording due to breakthrough from adjacent areas. If however standards are allowed to be relaxed significantly below those recommended here, programmes will be interrupted by breakthrough. This will cause not only additional expense due to retakes, and perhaps extended studio time, but also intense irritation, over the years, to the programme makers.

It is worth noting that remedial work to improve insulation at a later stage is far more expensive than if the work is carried out in the initial building stage. Indeed in some cases, say if additional floor loadings were not allowed for in the original design, the work would be prohibitively expensive. It is therefore strongly recommended that the standards set in this report should be accepted as the basis for future studio designs.

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Appendix 1
Data base for calculation of insulation requirements

This Appendix contains all of the base data from which the insulation criteria were calculated in decibel units of sound pressure level relative to 20μPa in octave frequency bands.

Studio, cubicle, control room and recording channel categories.

1. Radio – orchestral music/multipurpose
   Television – music, variety, light entertainment, general purpose
2. Radio – small music or recital
3. Radio – drama
4. Radio – talks, continuity, narrators
   Television – news, interview, unattended
5. Radio – 'pop' continuity
6. Radio – 'pop'

	octave band centre frequency, Hz							
	63	125	250	500	1k	2k	4k	8k
1. Background noise level criteria[9]								
Programme area, criterion (i)*	46	37	29	23	18	14	11	7
Programme area, criterion (ii)*	41	32	24	18	13	9	6	2
Programme area, criterion (iii)*	36	27	19	13	8	4	1	–
Reverberation plate room	63	54	47	41	37	35	33	33
Private office (NR40)†	67	57	50	44	40	37	35	34
General office (NR55)†	78	69	63	58	55	52	50	49
2. Source peak sound pressure level[8]								
Studio, Category 1	97	103	103	105	104	100	95	90
Studio, Category 2	86	92	102	105	102	97	90	84
Studio, Category 3	73	73	81	81	76	73	67	66
Studio, Category 4	73	81	84	85	80	77	72	68
Studio, Category 5	90	94	95	95	94	90	87	80
Studio, Category 6	112	118	116	115	114	110	105	102
Cubicle, Category 1	98	99	101	104	102	98	92	85
Cubicle, Category 2	71	79	87	89	84	82	75	68
Cubicle, Category 3	71	82	87	88	85	80	74	67
Cubicle, Category 4	71	78	82	81	78	75	69	62
Cubicle, Category 5	81	90	88	88	85	81	78	72
Cubicle, Category 6	106	108	104	105	101	102	97	91
Echo room	86	86	86	91	95	90	90	90
Listening room, dubbing theatre } Television control rooms }	98	99	101	104	102	98	92	85
TV Studio apparatus room	85	76	73	70	69	70	71	72
Scenery dock and construction workshop	78	80	83	85	85	85	85	80
Canteen and kitchen	74	75	79	84	82	76	77	71
Garage (uncontrolled)†	86	100	100	95	93	90	86	76
Garage (lower 90%)†	80	74	69	69	63	62	61	60
Private office	83	74	71	68	67	68	69	70
Private office with listening facilities	98	102	95	94	92	89	82	78
General office	90	83	79	77	74	74	74	68
Aircraft noise	93	92	93	92	93	92	90	–
Traffic noise	87	87	87	81	81	81	81	–
Plant room	81	81	87	87	87	88	88	88

* See Fig. 5   † See Section 4

Appendix 2

Sensitivity of a 'Kuhl' reverberation plate to external acoustic noise

A measurement was carried out on a large 'Kuhl' reverberation plate located in Studio 4 at the BBC's Portland Place premises to establish the sensitivity of such a plate to external acoustic noise as a function of frequency. The criterion used was that the acoustic breakthrough from the environment should produce an electrical signal at the plate output equal to the inherent electrical noise of the plate output amplifier. This is a severe criterion as the electrical noise output from the plate would rarely be a limiting factor. Nevertheless, such a condition could occur for special effects.

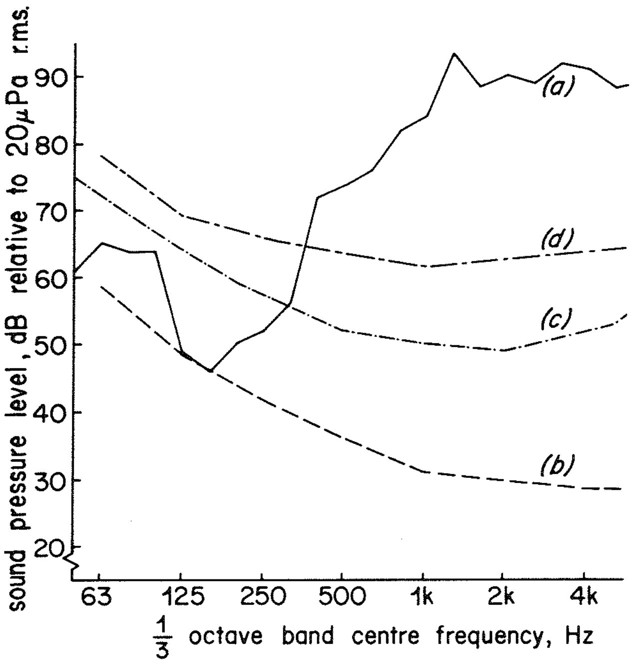

Fig. 12 - Sensitivity of a large reverberation plate to acoustic noise
(a) plate interference threshold
(b) private office background noise criterion from Ref. 6
(c) 50 phon noise level
(d) typical occupied private office noise level

Fig. 12(*a*) shows the external sound pressure level required to achieve the criterion in 1/3 octave bands relative to 20μPa. A weakness in the sound insulation around 160 Hz which can result in howlround if the plate is located in the control cubicle is evident.

Fig. 12(*b*) shows the background noise level criterion used throughout this report for a private office, converted to 1/3 octave bands.

Fig. 12(*c*) shows the 50 phon background noise level stated by Kuhl to be adequate.

Fig. 12(*d*) shows the typical noise level which exists in an occupied private office and implied in Reference 6 to be an adequate location for such a reverberation plate.

It is evident from these results that audible acoustic breakthrough to the plate output will occur at frequencies less than about 315 Hz unless the room containing the plate has a background noise level equal to or less than that in an unoccupied private office and *there is no internal generation of noise within that room.*

Appendix 3

Chart entries and method of reconstruction of a criterion

The entry in the chart for each combination of source and receiving area consists of six numbers arranged within a rectangular box.

D_{63}	$D_{15,10}$
$D_{10,8}$	$D_{8,5}$
$D_{5,0}$	f_0

These numbers are, reading left to right and top to bottom, the sound pressure level differences required of the partition at 63 Hz, the four intersections of the straight lines with the slopes 15, 10, 8, 5 and 0 dB/octave and the approximate frequency (in 100's Hz) at which the criterion curve becomes 0 dB/octave. For example:

34	52
60	62
68	07

This line can be reconstructed on a plot of sound insulation against frequency by beginning at a point 34 dB at 63 Hz and drawing a straight line, of slope 15 dB/octave up to 52 dB. At this point, the slope is changed to 10 dB/octave and the line continued up to 60 dB. The straight line at 8 dB/octave is then drawn between 60 dB and 62 dB. At 62 dB the slope is changed to 5 dB/octave and the line continued up to 68 dB. This final point should be at a frequency of about 700 Hz. At all frequencies higher than 700 Hz the characteristic has a value of 68 dB.

In some cases two numbers are repeated, for example:

52	65
65	82
87	10

In such a case, instead of changing from 15 dB/octave to 10 dB/octave, the change is made from 15 dB/octave to 8 dB/octave.

In other cases, more numbers are repeated, for example:

38	38
38	38
58	10

This represents a line, of slope 5 dB/octave, from 38 dB at 63 Hz to 58 dB at 1 kHz.

Some possible entries in the chart are not valid. This means that there is no requirement for sound insulation between those areas.

SMW/DS